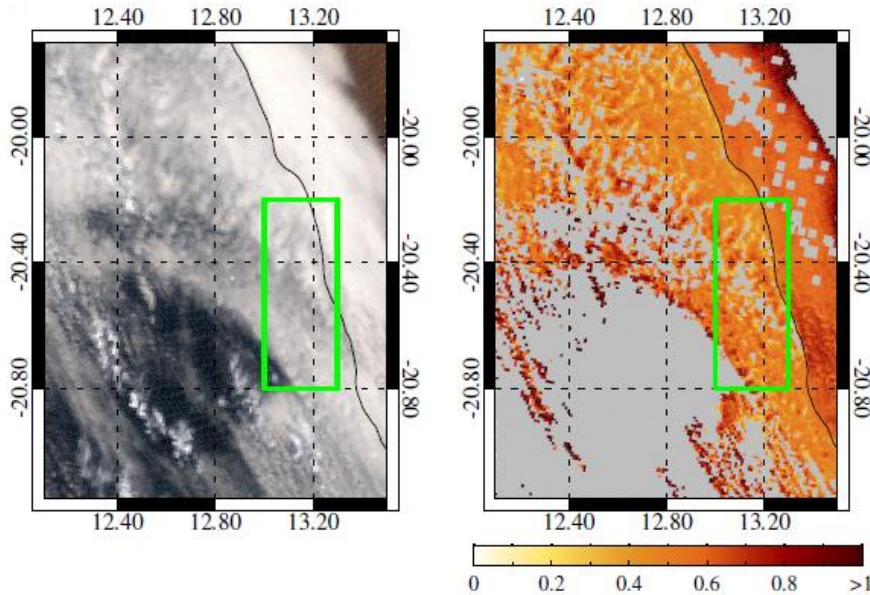


# A new method to quantify smoke and dust aerosols above clouds

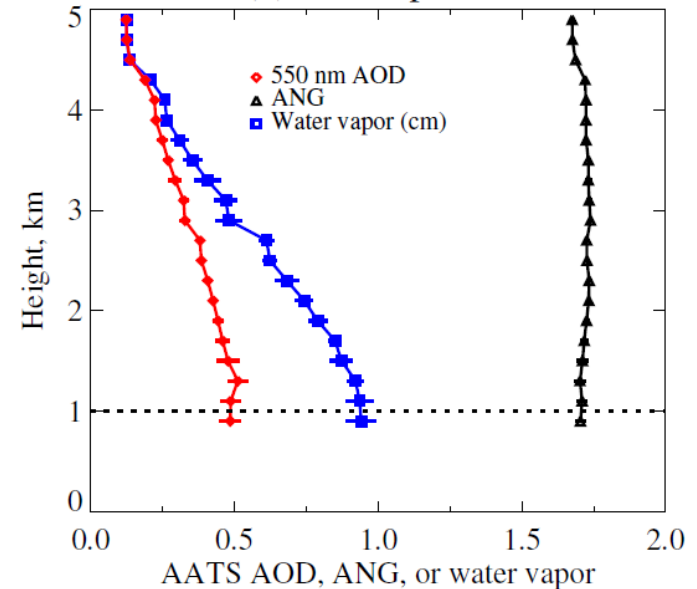
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(a) MODIS Terra true-color image (left) and AOD retrieved above clouds (right)



(b) AATS aerosol and water vapor profiles measured over the green box shown in (a)



Light-absorbing smoke and mineral dust aerosols above clouds (AAC) are omitted from most passive space-based aerosol optical depth (AOD) data sets. We developed a method to determine above-cloud AOD and liquid cloud optical depth (COD) from MODIS and similar sensors, for incorporation into the NASA 'Deep Blue' AOD data set.

Two MODIS scenes with AAC for which NASA Ames Airborne Tracking Sun photometer (AATS) data were available to use as a truth AOD data source were analyzed, demonstrating the validity of the technique with real observations.



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### References:

Sayer, A. M., N. C. Hsu, C. Bettenhausen, J. Lee, J. Redemann, B. Schmid, and Y. Shinozuka (2016), Extending 'Deep Blue' aerosol retrieval coverage to cases of absorbing aerosols above clouds: sensitivity analysis and first case studies, *J. Geophys. Res. Atmos.*, 121, doi:10.1002/2015JD024729.

This study was chosen for a Research Spotlight by AGU, and highlighted on the EOS website: <https://eos.org/research-spotlights/measuring-atmospheric-aerosols-despite-the-clouds>

**Data Sources:** NASA MODIS Terra, AERONET, and AATS data (collected as part of the SAFARI-2000 and ACE-ASIA 2001 field campaigns). Further information about Deep Blue is available at <http://deepblue.gsfc.nasa.gov>. The NASA Ames Sunphotometer-satellite team page is <https://earthscience.arc.nasa.gov/sunsat>. AERONET data are available from <http://aeronet.gsfc.nasa.gov>; the AERONET team and PIs, led by B. Holben, are thanked for the creation and stewardship of these data records. The efforts of those involved with the field campaigns are deeply appreciated.

### Technical Description of Figures:

These figures illustrate data measured off the coast of Namibia during the SAFARI-2000 field campaign.

**Figure (a):** A MODIS true-color image from 13 September 2000, of smoke-laden clouds off the African coast (left), and mid-visible aerosol optical depth (AOD) above these clouds determined using the new algorithm developed in this study (right). The green box indicates the region of a same-day flight of the University of Washington's Convair-580 aircraft, upon which the AATS instrument was mounted.

**Figure (b):** Profiles of AOD, Ångström exponent, and column water vapor observed by AATS during its spiral over the green box in (a). The dashed line indicates the cloud-top height of the stratocumulus cloud deck. AATS measures these quantities with high accuracy and thus is able to provide a comparative 'truth' to test the satellite algorithm. There are no systematic observations of aerosols above clouds of this type, and so the opportunities to validate this satellite data are rare; these field campaigns are highly valuable.

The mean and standard deviation of the AATS AOD around the cloud top were  $0.49 \pm 0.04$ . The corresponding values determined from MODIS were  $0.51 \pm 0.10$ , in very good agreement.

### Scientific significance, societal relevance, and relationships to future missions:

There has been increased interest in the space-based monitoring of absorbing aerosols above clouds (AAC) in recent years, particularly due to their effects on the Earth's radiation budget.

The direct radiative effects of these aerosols above a bright reflecting cloud are very different than those same aerosols above a darker land or ocean surface, and aerosol interactions with clouds may also influence the development of the cloud deck. The local atmospheric warming induced by AAC can lead to microphysical and process feedbacks in boundary layer clouds. AAC can also lead to biases in retrievals of cloud properties from space.

A final reason for the interest in AAC is data coverage. Most existing satellite AOD retrieval algorithms retrieve the total column AOD only for clear-sky pixels. In cloudy conditions, no retrieval is performed. This leads to significant data gaps in the derived satellite AOD records, and is doubly unfortunate because some of the large-scale recurring absorbing aerosol features, such as from springtime biomass burning in south-eastern Asia, occur in very cloudy environments. Extending the coverage of these data sets to include cases of AAC improves renders them more useful for monitoring aerosol transport or evaluating climate model output.

The techniques developed here can be applied directly to multiple past, present, and future NASA and international Earth-orbiting satellites, providing a means to decrease an important coverage gap in these data sets.